Sborník vědeckých prací Vysoké školy báňské – Technické univerzity Ostrava
číslo 1, rok 2009, ročník LII, řada hutnická
článek č. 1449

ON MECHANICAL DESIGN OF THERMOPLASTICALLY WELDED SHELL STRUCTURES

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ABSTRACT: Some aspects of structural design of cylindrical thermoplastically welded containers are considered in the paper. Implementations of welded thermoplastic shell vessels are connected by certain problems caused by generally insufficient flexural stiffness of thermoplastic walls of thin-walled structures in cases of external backfill loads. As it is shown, low wall stiffness causes not only high values of displacements, but predispositions it to the loss of stability of a construction at first. Influences of geometrical parameters and reinforcements of the shell structure on the level of buckling safety factor are studied with support of FEM analyses.

KEYWORDS: thermoplastic shells, reinforcement, buckling, FEM

1. INTRODUCTION

Thermoplastics sink into many industrial segments and pace of their applications is increasing. The reason for this is that classic materials do not fulfil the increasing technical needs. Without modern materials, series of innovating processes would not be performed. Specific properties of thermoplastics together with new processing and software technologies open wide possibilities of applications in variety of areas.

Every successful application of thermoplastics is conditioned by consistent constructional and technological preparation, and also by qualified determination of dimensions and shapes of projected construction. Thermoplastics are in general less stiff and tough, and they have significant inclination to flow, high coefficient of thermal expansion and significant dependence of mechanical properties on temperature. These properties are in general disadvantageous. On the other hand, there are unquestionable positives – easy processing, low energetic demandingness and high productivity of manufacture or wide possibilities of new technologies. Not less important is also resistance to aggressive stuff and environments, which thermoplastics specialize for building of devices, working in hard conditions of operations, with an example in chemical and food industry.

Specification of thermoplastics mechanical behaviour includes specialities and problems in process of propose beside classical constructions. Technology character and effort of mass decreasing, price leads to a fact, that constructions of thermoplastics are mostly proposed as thin walled. Despite this fact, ratio of stiffness to strength is in thermoplastics greatly low, so in series of examples is the definitive state of deformation for product proposal not only carrying capacity. Definitive marginal states can often be for proposal, having cause in construction stability loss.

2. BUCKLING RESISTANCE OF CYLINDRICAL SHELLS

An example of important role of buckling resilience would be shells of small wastewater treatment vessels, sinks, cesspools etc. They are made of thin walled cylindrical shells with inner structure, possibly dividing volume of a treatment on single sections. Outer reinforcement is then made of set-up of perpendicular and circumferential reinforcement sheets.

Working load is given by superposition of inner hydrostatic pressure with certain height of water level and outer pressure of external backfill loads – Fig.1.

Water level achieves some height, practically the height level of inner structure. Height of external backfill loads achieves mostly the height of upper part of vessel. Norm EN 12 566 defines backfill loads pressure curve in direction of height as linear. In basic operating state of load, inner hydrostatic water pressure and external backfill pressure are compensated.

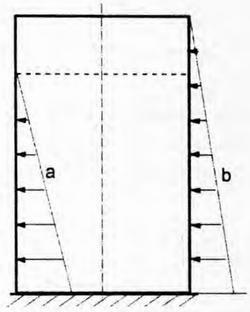

Fig. 1: Working loads: a – inner hydrostatic pressure, b – external backfill pressure

Analytical solutions of critical load determination are known as plain cylindrical homogenous and isotropic or orthotropic shells, loaded with radial outer pressure. These solutions allow determination of critical loading by stability loss of unreinforced sectors between solid reinforced ribcage [1]. They also allow verifications of FEM results.

In cases, when are the elements of inner structure being welded, or the series of reinforced inner circumferential and axial reinforcements is being used, FEM modelling has to be used.

Result of computation of linear stability of shell construction is a theoretical value of so called critical load, which corresponds to transition between stabile and labile steady-state of construction (indifferent steady-state at critical load). Critical load is in general upper estimation of construction stabile capacity. From final values of critical loads results relatively small, practically negligible influence of vertical bar of outer structure on stability of outer shell. Similarly, vertical inner reinforcements don't markedly contribute to increase of stabile capacity. From this look are outer welded circumferential cart-ladders most efficient. These are declined in many applications because of their consumption, thus their effortless vulnerability in process of drycleaner installation. They are mostly used as reinforced with circumferential straps, with thickness corresponding to that of vessel's coating.

Fig. 2 shows the result of stability analysis of a shell, especially with circumferential strap reinforcement in height of maximal reinforcement effect. Reinforcement increases the value of a safety to critical load from 1.56 to 1.94. Dependence of obtained safety on height is shown on Fig. 3. As one can see, optimal height is approx. 60 % of height.

Fig. 2: Stability of a cylindrical shell reinforced by circumferential strap of thickness 8 mm, width 100 mm, placed in optimal height. Safety in critical load is 1.94

Figure 4 shows the influence of dimensions of strap reinforcement on coefficient of safety and corresponding own shape of shell aberration, at identical height of reinforcement placement.

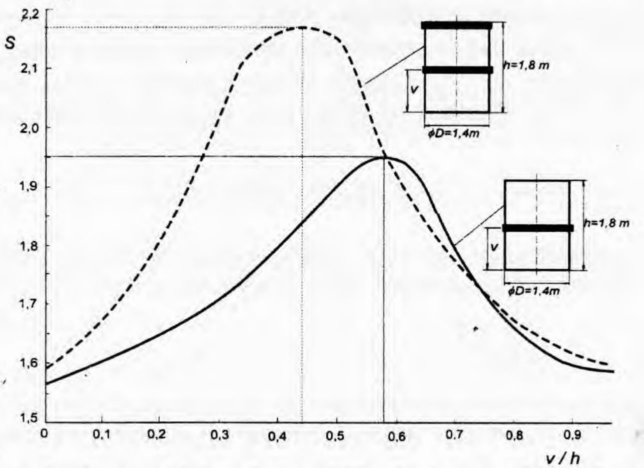

Fig. 3: Dependence of safety coefficient S on stability limit on position of strap reinforcements of thickness 8 mm and width 100 mm

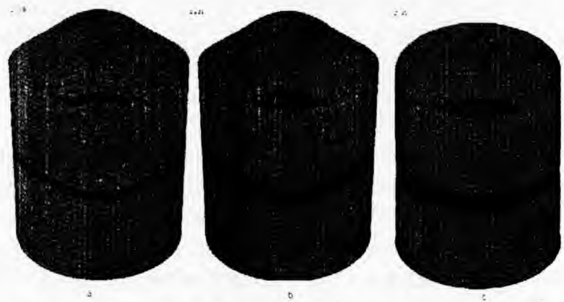

Fig. 4: Thickness and width of strap reinforcement's influence on stability of cylindrical shell: a – 100 x 8 mm, b – 150 x 8 mm, c – 150 x 10 mm. Safety a/b/c: 1.9 / 2.21 / 2.35

3. CONCLUSIONS

According to small values of bending stiffness of walls, welded shell constructions made of thermoplastic and their dependence on load period and temperature at their practical applications, the real danger of marginal state of stability loss of thin-walled shell is possible, resulting in abrasion and total destruction. As it results from this article, it is necessary to give the problematics of thermoplastic shells stability in their construction proposal enhanced attention. With that we can prevent their possible luck success in practical applications of these types of construction.

Acknowledgement: Article was prepared thanks to project MSM 708 352 102.

4. REFERENCES

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